from the water, except where the beds have been since locally altered, to a limited extent, by rivers and other streams of water cutting through them.

I am aware that erosion and changes in the elevation of land, of continental extent, occurred during Post-Tertiary time, but it is not probable that all the changes happened at the same time, and we must look to the respective changed localities to determine the relative ages when this work was done.

In this paper I have considered southeastern Kansas only, and have attempted to sketch the condition of things wrought out by natural forces in it.

IN THE DACOTAH.

BY ROBERT HAY.

Across central Kansas, from north to west of south, stretches a belt of country, marked in ravines by rugged sandstone rocks, and by long-rounded slopes on the prairie. This belt belongs geologically to the lower part of the Cretaceous system, known as the Dacotah formation. To travelers on the Central Branch Railroad, passing through Washington and Cloud counties, these sandstones are conspicuous objects. On the line of the Kansas Pacific, the same sandstones, underlaid by colored shales, make the wild country from Bavaria by old Fort Harker to Ellsworth. On the Santa Fé Railroad, a single hill standing out in the broad valley of the Arkansas, covered on its precipitous front with names of visitors—archdukes and naturalists—a hill of varied sandstone, capped with chalk, is the sole mark left by the tremendous erosion of a million years that here too the Dacotah formation occupied its place. Away north in Nebraska and to British America, away south in the Indian country and Texas, the same sandstones appear. The same, but varied—varied, but still the same.

At our northern State line, the surface-development of the Dacotah is about thirty miles across, forming the bluffs of the ravines on the west side of the Little Blue, and disappearing under the Inoceramus limestones of the Benton series in the west of Washington county, north and south of Haddam. Further south, the belt is wider, in some places exceeding fifty miles. This is probably due to a greater slope of the surface in the south, in past ages, causing greater erosion of superincumbent deposits.

The hill in the Arkansas valley is forever wedded to a tale of terror. It is the famous Pawnee Rock. But a little shred chipped from it tells another story. It is marked with the remains of an ancient flora. Further north, in Ellsworth county, are ravines with precipitous sides, on some of which a lost race has carved hieroglyphics of war and travel; and there are huge single rocks, like giant pulpits, standing out and alone. In Ottawa county are the worn pinnacles and crags of Rock City. In Washington county the bold sandstone cliffs are seen resting on permian limestone, while their upper surfaces have been ground by the huge hard boulders of the glacial age. And in all these places are the relics of the Old World flora leaves—dicotyledonous leaves. Other of our counties have them—Clay, Cloud, Saline—and they are found away north and south far beyond our borders. Professor Mudge and others have estimated the thickness of the Dacotah at about five hundred feet, and this thickness is composed mainly of sandstones, those near the top in most of the exposures we have seen, being light-colored, and the lower ones dark brown or red. In some places it is blood red, streaked with yellow; and when the sun shines on it we have a gorgeous glory. The coloring-matter is largely composed of some compound of iron, and in places this has oxidized in most curious forms, suggesting by their vitreous surfaces the action of fire. In many places we have picked up specimens with a botryoidal surface not to be distinguished from kidney hematite from Europe and elsewhere. Then there are nodules

of all imaginable shapes and sizes, rough vases, large troughs, bunches of fruits, hollow stems. It is easy to call these concretions. When we have said that, it is all plain! Is it? What is a concretion? A gathering together of somethings. What was the thing and the force that concreted and arranged the material of these balls, pipes, geodes? We have handled several thousands of these Dacotah concretions and examined many from other formations, and notwithstanding their multiform character we have come to the decided opinion that the origin, the starting point of the great majority—say nine-tenths of these in the Dacotah—is some organic form, mostly vegetable, about which the other material has been arranged in layers more or less concentric. A seed, a fruit, a nut, a twig, a snail-shell, a naked gasteropod, a spider, or a group of any of these, dead and decomposing; their organic juices, acids or alkalies have acted on the alkalies, acids or metals in the silt sand, or ooze about them, and so formed layers of iron rust, or chrome, clay or sand, which may have again changed and assumed the texture which we now find. We have concretions which can be arranged in a series passing from most fantastic forms through definite grades to those which are undoubted carpoliths, and as such are figured by our best fossil botanists.

The fossil remains of the Dacotah sandstones but rarely illustrate the fauna of that age. In two localities, over limited areas, marine shells of some score species have been found, and at one place, in Ellsworth county, we have a bivalve, probably estuarial, among the mass of leaves. From a well near Delphos, in Ottawa county, we have a mass of pyrites containing casts, both internal and external, of gomatites. Another compact arenaceous mass seems to be a saurian scapula; and the books tell of another saurian, from the clay near Brookville.

But if there be paucity of faunal remains in the Dacotah, there is no scarcity of the flora. The leaves are simply innumerable, and represent hundreds of species of plants, from the humble weed to the lofty tree. Fruits, clearly determinable as such, are however rare, and twigs, branches and trunks are rarer still. In the north of Dickinson county, one well-defined trunk has been taken out in sections and carried off by different collectors, and small branches are not scarce in that immediate locality. We have thought that some of the silicified and calcified logs of the Benton formation are probably Dacotah trees, suddenly killed at the end of the period. Fruits, certainly recognized, are those of juglans, prunes, and some other unnamed carpoliths.

The leaves described and figured in Lesquereux's "Cretacous Flora" belong to 130 species, while his new volume will have 17 additional plates of new species, and other species have been discovered this year. It is these leaves that have made the Dacotah famous. They are the earliest dicotyledons. Eighteen years ago Prof. Swallow, in the absence of fossils, ranked these sandstones as older than the Cretaceous system. When the geologists of the National Survey found the fossil leaves in Nebraska, Prof. Marcon pronounced the formation to be Tertiary. Now, certainly known to be Cretaceous, it is famous for the leaf forms distinctly allied to, and some identical with, modern species. Among the more conspicuous genera are Salix, Quercus, Magnolia, Sassafras, Juglans, Laurus, Ficus, Fagus, Liquidambar, Sequoia, etc., etc. As in our modern forests, the trees grew in groups, willow predominating in one locality, sassafras in another, and so forth. Lesquereux noticed this fact more than ten years ago. The leaves are distributed throughout almost the entire vertical extent of the Dacotah formation. They are found in the bottom sandstones and the shales beneath, as well as in all but the highest arenaceous beds of the series, where they are scarce, if not absolutely lacking. This is a vertical distribution of over 400 feet. It follows from this, that the forests, which supplied these masses of leaves, flourished through the period necessary for the deposition of over 400 feet of sandstone through the immense Dacotah area. If we go to a modern seaside, where the tides are strong, we may notice the layer of sand deposited

on some estuarian flat between ebb and ebb. It is possibly a small fraction of an inch between spring tides. In one place, in Ellsworth county, a deposit, filled with leaves from bottom to top, is from ten to fifteen feet thick. The leaves not huddled together, but evenly distributed, and often lying perfectly flat and straight. It was a time of what might well be called permanent conditions of climate. Yet there was all the while going on a gentle subsidence of the whole region, and this subsidence was the certain prelude of change, and the change came at last, and changes many have been since then.

We have, in collecting specimens of the Dacotah flora, encountered a difficulty in identifying species, which lies not only in the way of amateurs, but is also a trouble to specialists. The difficulty we refer to is that caused by not readily recognizing what particular form of fossil we have found, and which form is figured or described in the books we use. About fossil leaves, we remark that there are five forms, any one or two of which may be presented to us by a particular specimen, and all of which, for each species, should be in position in a typical cabinet.

1. There is simply the impression that the leaf may have left on the material with which its *upper* surface was in contact.
2. The similar impression made by the *under side* of the leaf.
3. The leaf itself may be petrified, and we may see the *upper* surface of it.
4. The petrified leaf may be adhering by the upper surface, and we may see the *under* side.
5. The leaf itself may all have been dissolved away without other material taking its place, leaving a thin cavity between the impressions of the upper and lower sides which a tap of the hammer may lay open.

These same forms, essentially, if not numerically, occur for all kinds of fossils. A locality a few miles from Lawrence gives us beautiful internal and external casts of a gasteropod-pleurotomarid sphærulata, as well as the fossil itself. We have on the table a plaster cast taken from the external impression of a Dacotah bivalve. Having often experienced the difficulty above referred to, and sometimes found specimens of which the form was readily distinguishable, we have thought it worth while illustrating this point by some experiments in plaster with leaves from trees now growing in Kansas. And we have a few fossils illustrating some of the forms. Those fossils best illustrating forms three and four are those of thick coriaceous leaves.

BUILDING STONE.

In Ottawa and Washington counties, the Dacotah yields a heavy, dark-brown stone, which can be readily worked, and where used in squared blocks makes a very handsome building material, and is well set off by sills and corners of the neighboring Benton, or Permian, limestone. The rough, ferruginous sandstones, and even the softer varieties, supply building material of various qualities all through our Dacotah region.

COAL.

In several counties—Washington, Republic, Lincoln, and Russell—seams of an inferior quality of coal have been found. It is lignite, having much pyrites and a large quantity of ash when burned. It is, however, of some use as household fuel where the thickness of the seam is sufficient to pay for working it. Professor Mudge indicates that there is *one* horizon for *several* of these seams. It would be valuable geological service to determine the position of that horizon, and if it was a continuous seam now broken by erosion, or whether the localities indicate a series of islands or basins. Though the term lignite indicates the presence of wood fiber, yet we have no idea that any considerable part of this material was wood, for it has been shown conclusively by experiments, the results of which are confirmed by our experience of modern forests, that wood fiber, especially of the higher kinds of trees, is not preserved in the conditions under which coal was formed, so well as material of the leaves, stems and seed vessels of the under-

growth of ferns and other plants of the lower vegetable orders. But the immense numbers of leaves in the Dacotah sands indicate forests on the land, whose undergrowth through ages must have left a carbonaceous deposit which, entombing and preserving some trunks, may well be the lignite of to-day. And here is another problem. Was there not a lignitic stratum formed in immediate proximity to every thick deposit of leaves? In other words, may the leaf deposits be taken as "*indications*"— in the miners' sense — of lignitic coal? An extended examination of many localities would have to determine this.

CELESTITE.

Just outside Salina, on the east of the town, is a hill of Dacotah sandstone. On the southeast this hill is cut into a bold front by the Smoky Hill river and the excavations for a flouring mill. This front shows the upper layers of the permo-carboniferous rocks and shales. A few miles south, the cavities in these upper layers yield beautiful crystals of celestite — the discovery of which is to be credited to our friend Mr. Warren Knaus. In Washington county, northeast from the county seat, a bold bluff overlooking Mill creek is capped by the sandstones of the Dacotah, and is marked at a lower level by a thick ledge of permian limestone which is again underbedded with gypsum. At the west end of the bluff the Dacotah is eroded, and the permian ledge is quarried, and here the writer found last spring the beautiful flat crystals of celestite, such as were found in a similar position in Saline county. Another problem! We know that sea water contains, besides other salts, a supply of strontia. Were those crystals of the upper permian cavities deposited by infiltration from the Dacotah sea, and may we not expect in this horizon somewhere a supply of this mineral which will have a commercial value?

ARTESIAN WELLS.

We are led to think from many observations that an important if not the chief item in the economic value of the sandstones of the Dacotah will turn out to be their capacity of holding water and supplying it to a large part of west-central Kansas, beyond their area of surface development. The dip of the strata appears to be mainly west and by north. We pointed out a year ago that there are indications that the rocks of western Kansas have an easterly dip. Putting these facts together, we infer that somewhere between the two regions there must be a synclinal trough, and along the line of that trough water will mostly be found in the sandstone in sufficient quantity, of good quality or more or less impregnated with iron or other minerals. The sinking of test wells in several counties by State authority after a careful surface survey would surely pay. Owing to the fact that the surface west of the Dacotah is more elevated than in its own region of exposure, these wells could not be flowing wells — though the water might be expected to rise in the tube — unless, as sometimes might be the case, cracks and fissures in upper cretaceous strata gave local supply from the west. In the west of Mitchell county there is a true flowing well in an outlier of the Dacotah, though the source of supply is probably partly in the surface deposits — tertiary or alluvium. We refer to the famous Great Spirit Spring near Cawker City, the geology of which, we believe, has not before been described. It is a natural artesian well in the Dacotah.

CONCLUSION.

Dr. Peale and others of the National Geological Survey describe the development of the Dacotah, in the mountains of the west, as being in places metamorphosed by igneous action and elsewhere flexed and folded by tremendous forces. None of this appears in Kansas, but the relation of this formation to the Benton above and the Permian below is very like its position as described by Hayden and Lesquereux, in Nebraska. Before writing this paper we consulted such descriptive works as were within our reach, and while regretting that we could not obtain Hayden's Report for 1867, yet we were forci-

bly struck with the fullness and accuracy of the description given by Prof. Lesquereux in 1874, in his volume on the "Cretaceous Flora." Further, the more we look at the work done by our late esteemed friend Professor Mudge, the more we are impressed with the carefulness of his observations and the general justness of his conclusions. Hugh Miller tells us that wherever he followed in the track of Sir Roderick Murchison, he found all that geologist's work exact—the outline correct; only details to be filled in. We believe it is so with Professor Mudge. What he did, *was* done, and can be taken as a starting point for succeeding geologists.

We have given some description, we have indicated some problems, but we cannot now stay longer IN THE DACOTAH, except to say that our description falls much below the beauty and the wildness of this region; and that the solution of these problems will add much, not only to our stock of knowledge, but also to the material wealth of this, the Central State.

NOTES ON THE GEOLOGY OF THE SPANISH PEAKS.

BY J. SAVAGE.

Like most volcanic mountains, the Spanish Peaks stand isolated and alone. They are twins, and are known as the east or west peaks. When seen from a distance, their outlines stand out sharp and pointed against the sky. The east peak is entirely volcanic and destitute of mineral veins, and is the smaller of the two.

The west peak has a volcanic nucleus, or cone, but has a thick outer covering or mantle of the later sedimentary rocks. This outer blanket of soft sandstone has, by the intense heat of the inner volcanic material, been metamorphosed into hard, silicious quartzite, in which are found many metallic veins of the precious metals, besides abundance of lead and traces of copper.

Cotemporaneous with the elevation of the Spanish Peaks, and radiating from them like the spokes from a gigantic wheel, are found a remarkable system of dykes. These dykes are composed of varying volcanic material, and stretch off into the surrounding country from ten to twenty miles in extent. They were thrust up through the soft, friable sandstones of the Colorado lignite, in a soft, doughy state, leaving the impress of the sandstone mould all along their entire length. Near the peaks. where the power of erosion is much greater than elsewhere, the sandstone mould has been worn away, leaving the harder and more silicious dykes still standing as plumb and straight as a masoned wall, from 200 to 250 feet high; while further out in the surrounding plains, they have weathered down into sharp, steep knobs and peaks, thus presenting a picturesque and varied outline to the surrounding scenery.

Fisher's Peak, near Trinidad, is a notable example of one of these dyke remains.

The dykes, as they enter the west peak, are said by the miners to be converted into true fissure veins, and from what I could learn during a short climb up the mountain, I should judge their conjecture to be true. These mineral veins seem to penetrate the entire mountain, and divide it up into regular sections.

Near the base of the mountain, one dyke often cuts another in two, showing the one thus cut to be the older, but still soft and plastic when the newer one divided it in twain.

In approaching the peaks we find the strata gently dipping toward them, as though the giving out from beneath of so much volcanic material as composes the peaks and the dykes had left an empty space below, now occupied by the depressed strata.

I know of no richer field for exploration by young geological students, in all the Rocky Mountain region, than these Spanish Peaks, and the lessons learned from their study may be summed up as follows:

1st. All sharp-pointed mountain-peaks, whether seen from near or from far (and we

†1510. Carex marcida Boott. Rooks county.
1511. C. hystricina Willd. Salina.
†1512. Polypogon littoralis. Salina.
†1513. Aristida desmantha Rupt. Harper county.
1514. Eragrostis Purshii Schrad. Harper county and Salina.
†1515. Triticum glaucum. W. Kansas.

ERRATA.

Page 110, 21st line, for "gomatites" read *goniatites*; in 32d line, for "prunes" read *prunus*.